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THE METAPHYSICAL IMPLICATIONS OF THE PRINCIPLE OF RELATIVITY.

THE Principle of Relativity is a mathematical principle by which spatial and temporal measurements are coördinated for observers in systems of reference which are in movement relatively to one another, and by which the equations are transformed when the observer passes from one system to another. Before we can understand the principle it is essential to understand the problem.

Let us suppose that while we are seated in a room some genie, like the genie of the lamp in the story of Aladdin, were to transport the room at a high velocity to some other part of the world, are there any means by which, limited to inside observation, we could know that the room was moving and could calculate the velocity and direction of the movement? Or, let us suppose that it is not the room by itself, but the whole solar system which has suddenly started a movement through space at an enormous velocity, impelled, we may imagine, by the kick of some Micromegas at play in the universe. Were there no astronomers or other folk observing the stars, is there any purely terrestrial phenomenon, anything which would necessarily undergo alteration on the earth itself, by observing which we could know that we were being translated in a definite direction at a definite speed? Until a few years ago when the important experiment which I am going to speak of was made, it was thought that optical phenomena observed under laboratory conditions would reveal such a movement of a system, could even reveal its direction and velocity, without any need to resort to observations of objects outside the system. The ground of this belief was the theory that light was transmitted in a medium at rest, that is, a medium not participating in any movement whatever of material systems. The medium was named ether, and it was distinguished as that which could not move from matter which could move. The difficulty of testing this belief was the practical one that, as the transmission of light in ether is at an enormous velocity when compared with any material movement known to us, the variation of this velocity due to a material movement must be too small to detect. Were, however, our system to receive an impulse such as I have supposed, giving it (relatively, say, to the 'fixed stars'), a velocity at all approaching the velocity of light, the change such movement would produce ought to be so great that it should be easily observable. Whether the ether is an actually existent entity is unimportant. What is important in the theory is that the ether is at rest while the material system moves. Let us imagine then that we are seated in a laboratory furnished with accurate optical instruments. We have the means of producing a beam of light, throwing it on a mirror placed in any direction we wish, and receiving it reflected back to us. And now our room begins to move. Let us suppose the velocity of the movement is half the velocity of light, then as we move and the light is propagated in a medium which does not move the beam we throw out at right angles to our direction will lag behind us. If we send two beams one in each of the two directions at right angles at the same instant, they will not be reflected back at right angles.

This was the supposition before the famous Michelson and Morley experiment. It was to test this theory that the experiment was designed. The difficulty was to find a movement with a velocity great enough to show the aberration, and an instrument delicate enough to record it. The experimenters used the earth's movement of translation in its orbit round the sun combined with the movement of the solar system through space, and so obtained a movement of translation for their experiment, which, though only 1/10,000 part the velocity of light, was yet a far higher velocity than that of any material movement we can produce. The instrument was contrived to show a variation in the velocity of light, as small as the 100 millionth, and this was at least one hundred times smaller than the variation they expected to find.

The experiment was such as I have already imagined in my fanciful illustration. The mirrors were placed in the two directions, parallel and perpendicular to the motion, and the whole could be rotated so that the positions of the mirrors could be reversed. A beam of light was arranged to pass from a source to each mirror whence it was immediately reflected to an observer and the expected shift of interference-fringes on rotating the apparatus was exactly calculated. But the result thus calculated was negative. No shift of fringes was observed, and if any existed it must have been at least two hundred times smaller than it ought to have been, and no reason was given to suppose that an effect even so small as this existed. Other experiments have since been made and all confirm the result, which is described as uniformly, even obstinately, negative.

Two important facts seem to be established by these experiments. The first is that it is impossible to discover the uniform movement of a system by optical experiments within the system. For example, to discover that the earth is moving without observing the sun and stars. And the second is that the velocity of light is constant for every observer, it is independent of the movement of the source of light.

These are the two experimental facts on which the theory of Relativity is founded. Before I try to show the revolution it has brought about in our ordinary notions of the nature of space and time, and in the concept of physical reality, let me give one more illustration drawn from fancy to show the difficulty there might be in discovering the alterations of the spatial and temporal proportions of our universe, should we find in the theory of relativity a reason to believe that space and time vary when moving systems undergo acceleration.

Suppose that Gulliver when shipwrecked on Lilliput, instead of waking up in his old proportions, had undergone during his sleep a shrinkage to Lilliputian proportions, he would not have been able to discover that anything unusual had happened to him. It would have been impossible for him to know either that he himself or that the physical world had undergone a change. Yet he would have passed into a world in which all reality, spatial and temporal, with all the standards of measurement and all the clocks, had shrunk to one-twelfth of the proportions of the world in which till then he had been living. Compared with the former world feet would now be inches, and an hour would be five minutes. But as he himself would have shrunk to one-twelfth of his physical proportions he would be, and would continue to be, unconscious of any change of condition in his world. Physical reality would have suffered a complete snap, but psychical experience would have been continuous. Suppose that after a stay of one year, reckoned by his former system, twelve Lilliputian years, he were to return to his former world, and on returning were to be restored to his old proportions. He would still as before be unaware, and unable to be aware, of the new change in his spatial and temporal universe. But revisiting his family and friends, he would discover a strange discrepancy. He would have been absent one year, but would have aged twelve years, and his old world would be eleven years younger than he would expect to find it, for he would have been twelve years in Lilliput. If therefore a great change were to take place in physical reality, altering spatial proportions, altering temporal rate of flow, deforming the material universe, so long as we the observers continued ourselves to undergo the corresponding change we could not discover the fact. However great the alteration the world would remain for us the same world. And there is only one way in which in such case we could become aware of the change, and that is that we should be able to compare our experience with that of an observer who would not like us have undergone the change, but would have remained in the system we had departed from and returned to. Suppose now we ask ourselves what is the relation of Lilliputian space to our space and of Lilliputian time to our time? It is clear that we can give no answer, or rather that the only answer we can give is that on the objective side there is no relation. They are not reconcilable with our ordinary notions of the conditions of the physical world. The Lilliputian space is not contained within our twelve times greater space, the Lilliputian time is not part of our twelve times slower time. If it were there would be a remainder, and there is no remainder. There is a one to one relation between them, but only for an observer who is able to pass out of the one system of reference into the other without himself changing with the change. Observe that in this illustration I am not supposing, as in Swift's satire, that these lands with inhabitants whose proportions are different from ours occupy some region of our own earth, and that their history is contemporaneous with ours. I am supposing that their space and time are actually different from ours.

According to the Principle of Relativity a change of the kind I have imagined is taking place at every moment. Space and time and matter do not exist independently of the movements which are taking place. The earth's rotation on its axis, and its annual motion, and the acceleration of the earth's movement in its annual revolution round the sun, involve a change in spatial and temporal proportions, a change which we cannot observe because we ourselves undergo the corresponding change in our proportions. We are in fact continually passing and repassing from Lilliput to Brobdingnag, and the truly extraordinary thing is that we should be able to discover it. It is a discovery of this kind to which the experiments have led, and upon this discovery the theory of Relativity is based.

Let us, then, examine some of the consequences which the acceptance of the theory of Relativity involves. I will take first the doctrine known as that of the abolition of the ether. The postulation of ether as the medium filling interstellar space was a necessary consequence of the undulatory theory. The notion of undulation or vibration involves as part of itself the notion of a medium which undulates or vibrates. There cannot be wave motion with nothing to support it. This necessity rests on the rejection by physics, as a fundamental axiom of the science, of the possibility of immediate action at a distance.

Electric and magnetic actions therefore can only be transmitted from point to point through space by the interposition of a medium. There was no such medium known or that it was found possible to make evident to sense perception. Ether had therefore to be hypothetically assumed. The argument still holds good, and physicists will no doubt continue to speak of ether in connection with undulation of light even when they are driven to deny to it every quality consistent with existence. The argument may be simply illustrated. It takes eight minutes for the light emitted by the sun to reach the earth—where is it during those eight minutes if there be no medium to transport it? And the negative argument based on the absence of any positive quality whatever that can reveal it is met by the familiar fact that the existence of air would be unknown had we no air pump. The ether pump may be awaiting discovery. Sir Oliver Lodge, who continues to support the ether hypothesis, meets the negative argument by pointing to the impossibility of conceiving that deep-sea creatures, however advanced in intelligence, could be aware of water. The notion of a luminiferous ether has had a strange and eventful history. At first a mere hypothetical x, it soon became a physical reality constituted with regular attributes and calculable in its action, finally supposed to be the primordial substance of the universe out of which matter itself has been generated. It was endowed with strangely contradictory attributes—frictionless, solid, incompressible, immovable, fixed and yet strainable, enduring unaffected the translation through it of matter. Not that there is anything necessarily fatal to it in the fact that its attributes seem self-contradictory; the reconciliation may merely await fuller knowledge. The theory of atoms has survived and developed, although serious logical difficulties in the conception of the atom were obvious from the first. And, indeed, we are not free from logical contradictions in any case, whether we hold that ultimate physical reality is continuous or whether we hold that energy and even time itself is atomic. The Principle of Relativity has deprived this hypothetical ether of every property but one, the absolute constancy of light propagation. But as this absolute constancy is for every observer, whatever his own system of relative movement, instead of one absolute ether filling space, at rest and unalterable in relation to all systems of movement whatever, we must conceive the ether to be carried with and belong to every system of movement. Instead of one ether we must suppose infinite ethers, as many as there are systems of movement, and one for every acceleration of a movement, and to suppose this is precisely the same thing as to suppose there is no ether. Or we may state the argument against the ether hypothesis in another way. If light move at a constant velocity in an absolute ether, then to an observer in movement of translation relative to the ether, the velocity of light must appear greater or less by the amount of the observer's own velocity according to its direction. This expectation experiment has falsified. The velocity is constant, therefore the ether is of no use and may be abolished.

It follows also from the Principle of Relativity that neither space nor time is absolute, each is a function of the observer's system of reference. One and the same event which for observers in one system of reference is at one moment and in one point, is for observers in another system of reference two events separated by distance in space and interval in time. The familiar and simple illustration is that of objects dropped through the floor of a moving wagon. Two objects dropped in immediate succession is an event that to observers in the wagon occurs in one place and at one time. To observers on the soil they are two events separated in space by the distance travelled by the wagon during the time of their occurrence. For observers on the soil, for whom there is separation in space, there is also a time interval which does not exist for observers in the wagon. There are no two events separated to our observation in space for which it is not possible to conceive a system of movement of translation for observers in which they would be in the same place, and likewise there is no one event which for us is in one place and which might not for some system of reference be two events at different places. It was at first thought that at least time must be absolute, but it is clear that by the principle the time interval is different for different observers; it must be shorter for observers to whom events occur in one place than for all other observers of those same events. Space and time therefore change and undergo alteration when we pass from one system of reference to another. One thing alone remains constant, the velocity of light. This velocity therefore assumes of necessity a rôle of the first importance in the new kinematic theory.

This new conception of the velocity of light as a finite critical velocity is also paradoxical when judged by ordinary notions. The velocity of light must be conceived as a constant finite velocity and also as a maximum velocity. And the Principle of Relativity introduces a new meaning into the conception of simultaneity. Two events can only be simultaneous if they are in the same universe, and they are only in the same universe if the distance which divides them in space and the interval which separates them in time are coördinated with the velocity of light.

The Principle of Relativity therefore regards every observer as the centre of a universe in which all events are coördinated for his system of reference by four coördinates, three for space and one for time, all variable. They undergo alteration with every change from one system to another, and with every change of acceleration of a system, and the only constant is the velocity of light. Let us illustrate it by an extreme case. Let us suppose that, from being an observer fixed to this system of reference we call our earth, one could be transferred to a system, say an atom, in which life as compared with our present life would pass in some thousand millionth of a second. Suppose now that from our new position on an electron we look out on to our new atomic system in place of our old solar system. One thing only will have remained constant, the velocity of light. Suppose then that our new system of reference is such that the light radiating from the centre of the atom takes eight minutes to reach our electron; then 90,000,000 miles will separate us from the source of light in space. The relation between this new space and time of the atom and the old space and time of the solar system will have nothing in it that is absolute, each is a function of the relative velocity of the observer's system. Each observer will have eight minutes of time interval and 90,000,000 miles separating his light from its source, but there will be no standard for comparison of the space and time, the one will not be contained within the other. Five minutes of our old system may be a geological period of our new system. Einstein has calculated, for example, that were we to leave the earth in a system of translation moving at 1/20,000 of the velocity of light and were to remain absent two years and then return we should come back to a world that had aged 200 years in our absence.

The theory has also led to profound alterations in the concepts of inertia and of mass as they figured in the old rational mechanics. These concepts undergo an entire transformation in the new kinematics. In the ordinary popular notion mass is quantity of matter. In the new theory, the inertia of a body is seen to depend upon the energy contained in it, and this implies a fundamental identity of mass and of energy. From this it can be shown that radiation must have a 'mass' and that mass is a function of velocity. Many controversial and unsettled problems arise however at this point with which it is not my purpose to deal. But it is easy to see that the discovery which has led to the formulation of this new principle must, if it is established, bring about a profound change in our ordinary notions of the nature of the physical universe. What is its significance? To mathematicians it is a very simple matter. It merely changes one postulate for another and works out a new set of equations on the new postulate. To physicists it represents a complete alteration in their conceptual framework of the universe. What are its relations to philosophy? Are there any metaphysical consequences implied in the new conceptions? I think there are, and I will now try to indicate them.

From the standpoint of mathematics and of physics it may easily seem that philosophy has no concern with the matter whatever. The principle is founded, it will be said, in scientific experiment and depends from first to last on scientific facts. Philosophy cannot decide for the physicist whether there can be a movement which exceeds the velocity of light; whether, for example, gravitation is or is not such a movement, whether or not ether is an actual physical existence; whether, if it be, there can or cannot exist the means of making it manifest; whether it is necessary to suppose a real ether as the condition of the formation of an electro-magnetic field; whether energy is discrete or continuous. These are not metaphysical problems and metaphysics possesses no special means of solving them. On the other hand it is not difficult to show that the ether hypothesis is more than a scientific theory. It is a philosophy. It arose out of the logical necessity of representing the continuity of the universe. It is an attempt to represent that continuity in physical terms and on a physical principle. The failure of the hypothesis cannot be without relation to the main problem of philosophy.

The problem of continuity may be said to be the main problem of philosophy. What is the kind of reality which makes the universe one? Is it the kind we attribute to a thing or the kind we attribute to a mind? Are matter and energy the origin of the activity we experience in life and consciousness, and observe in external nature? And is some mode of matter and energy primordial? Or, is mind original and are matter and energy derived? To this problem the fate of the ether hypothesis is not indifferent, whereas the ground of its rejection, and the necessary choice of a new principle consequent upon its rejection, directly challenge metaphysical enquiry. In the most literal sense the principle of relativity leads beyond physics.

An ultimate discontinuity is unthinkable. This may be illustrated in many ways. The simplest is, perhaps, to show the vanity of the attempt to represent pure nothing in thought. Absolute nought is a pseudo-idea. It is the abstraction by thought of every order of reality. Could such abstraction be completely successful it would end, not in an idea of nothing, but in no idea at all. When we speak of nothing we find always that what we are thinking of is something, and it is the absence of this something which we try to represent in idea, but the something is always present in idea, even when we imagine it absent in fact, and we are always ourself there in thought contemplating the void we imagine. Even the conception of an ultimate discrete reality, atoms and the void, is not the idea of an absolute discontinuity. The void is the potential place of an atom. It is therefore not nothing. Continuity seems to depend on a physical principle. It appears absurd to suppose that the universe can hold together unless there is some entity, comprehensible by physical science, supporting the influences which radiate from part to part. If the continuity cannot be matter we must suppose ether, if it cannot be ether we must suppose at least geometrical space. The Principle of Relativity, whether its formulation is final or an approximation only, is based on the impossibility of regarding any physical entity, actual or hypothetical, as necessarily continuous. Continuity is not dependent upon an entity independent of the observer. It is the observer himself.

We ordinarily distinguish two kinds of continuity, namely, physical continuity and psychical continuity. The distinction is familiar enough, since it enters into all discussions concerning what constitutes personal identity. The scientific basis of continuity is illustrated in this doctrine of ether, for it was out of the necessity of finding such a basis that the doctrine arose. Were there any completely empty spaces, that is voids, in the physical universe, radiation would be inconceivable. There must be, therefore, in order that radiation may be conceived, a medium filling space. Matter cannot be that medium, for however tenuous we may imagine its form, yet its essential character is its mobility. Ether is conceived as a medium which is immobile. It may be strained but cannot be moved. There are no interstices in it. The contradictions, logical, physical and mathematical which the notion contains have always tended to leave its real existence in doubt; but even when its creators have been doubtful of its existence they have never been in doubt of the existence of a physically real space which would be empty if there were no medium filling it. Space in fact is itself often conceived as an entity in physics. Many now suppose that ether is unnecessary and that all that is wanted for the conceivability of radiation is the formation in empty space of the electro-magnetic field. But some kind of entity which will enable us to form an idea of continuity seems essential to the conception of the physical universe. And this entity, whatever it be, ether or empty space, is immobile and unchanging.

The notion of psychical continuity presents a complete contrast to the notion of physical continuity. Instead of an entity required to be immobile and unchanging, it is change itself which is continuous. A psychical continuity is an identity which is preserved throughout a becoming which is absolute. This is true duration. This is, of course, the well-known theory of Bergson. Duration is not a succession of states that exist separately as states. It is neither temporal nor spatial in the sense in which space and time are modes of the external relations of a thing. Duration is essentially indivisible, and therefore not quantitative. It is quality, not quantity. If we think of life or consciousness as true duration, the parts of it are not spatially or temporally distinct within it but interpenetrate it. It is not therefore this kind of continuity that physics studies. If then we are forced by the Principle of Relativity to recognize that no kind of physical continuity can be ultimate, must we not seek this continuity, which is a necessity of thought, in mind? Is there any other way of interpreting the experimental conclusion that the velocity of light is constant for observers in different systems of reference? That ultimate continuity is psychical seems to me clearly and necessarily implied in the negative conclusion on which the Principle of Relativity is founded.

When we turn from the relativist doctrine of the abolition of the ether and consider the relativist theory of space and time, it is even more evident that ultimate continuity must be life and not something which lives. Whatever may be our view of the ether hypothesis, the conceptions of space and time cannot be indifferent to philosophy. The nature and origin of these conceptions are recognized problems of psychology and of metaphysics, and the consideration of them has given rise to many different theories.

In mathematics space is taken as constant and time as independent variable. In geometry space alone is considered. In chemistry space and time are both constant. In mechanics space and time are both constant and are represented as the homogeneous background of movements and events. In the theory of relativity both space and time are variable. The three dimensions of space and the one dimension of time are four axes by which every event is coördinated with other events in a universe which is conceived as consisting of events. The coördinates are not absolute and independent, but tied to the event, relative to the observer and varying as his system of reference varies. Thus, for example, the acceleration which brings about a contraction of one axis of an observer's system relative to another system shortens the scales in proportion to the lengths measurable, alters the clock with the rate of flow of the system, so that continuity is maintained for the observer who has changed his system of reference.

The relativity of space and time is not a new doctrine. Indeed, when we consider the psychological origin of the conceptions of space and time, their relativity seems the natural conclusion to which the facts point. What is new in the relativist doctrine is the denial that there is any absolute space and time which can be taken as a standard of reference in physics, a standard by which all observed spatial and temporal relations can be regulated. It seems easier to admit this doctrine in regard to space than it is in regard to time. There are many considerations which seem to make it at least extraordinarily difficult to recognize an absolute space if such does exist. But with time it is different. Time seems to have something necessarily absolute about it. The moving point which divides our past from our future and which we call 'now', seems in its nature absolute. It must, we think, be one and the same for every system of reference whatever other relations systems may have. This 'now' seems to mark an absolute limit, in the sense that every event is in a time order of before and after in relation to it. This is one reason why time appears to have an absolute character which does not necessarily belong to space. There is yet another reason, namely, that time considered as a dimension, unlike the three dimensions of space, has an irreversible direction. On this irreversible direction depends the relation of cause and effect, and it seems therefore that were time not absolute we could not assert the priority of the cause to the effect. Were the direction supposed reversible there would be systems for which effects would precede causes. This is the reason which Einstein gives for holding that a velocity exceeding the velocity of light is impossible. To the observer in a system moving relatively to other systems with a velocity exceeding that of light, effects would happen before their causes, and consequently the observer would be regressing in time.

The theory of the relativity of space and time, though often advanced in philosophy, has always appeared inconsistent with physical science. What is new therefore is its promulgation as a principle of physics and its recognition in the formulation of new mathematical equations. It is, however, just this physical form of the doctrine which is in accord with the philosophical distinction I have already noticed between duration and time. Duration is not a dimension, it is not in itself either a relation of measurement or an aggregate of units, or divisible into separate parts. It is simple and indivisible. Duration is not time, intervals of time are not intervals of duration. Quantitative distinctions are external to duration, brought about by viewing it against an intellectual background or scheme. Have we not in this doctrine the exact counterpart of the physical theory of relativity? What is ultimate is the change or becoming which constitutes the duration of the observer. What are variable are the axes of coördination, space and time, by which the observer unifies his external observation for his system of reference. What is constant is a relation of these axes of coördination. It is this constant relation for the observer which makes the phenomena of the external universe identical, however much, looked at from an independent standpoint, the system of reference may change. Is not this in effect to admit that the continuity of the universe is psychical?

It seems a great paradox to ordinary common sense to affirm, not merely that our experience of space and time is relative to ourselves, to our interests, to our attention, or to our mode of sense-apprehension, visual, tactual, auditory or muscular, but that there is no absolute, physically real, space or time which our senses more or less adequately apprehend. Yet the argument is based not on psychological and metaphysical grounds but on mathematical and physical grounds. The relativity of space and time is a logical not a psychological postulate. But when we turn to the new theory of inertia, which depends on the doctrine that mass is a function of velocity, we seem to come up against a plain and glaring contradiction. The theory seems opposed alike to ordinary experience, and to intelligible scientific theory. "It is to the self-induction of convection currents, produced by the movements of its electrons, that the atom, which is formed of them, owes its apparent inertia and what we call its mass."[1] That an immaterial particle should possess mass seems contrary to our habits of thought, and is difficult if not impossible even to represent in thought. Mass and matter we commonly regard as one and the same thing. We ordinarily think of mass as quantity of matter. Even when we recognize that weight is a relation of masses and that the weight of any mass tends to zero as it is removed from other masses, while the mass which thus loses weight yet itself remains constant, it still seems a necessity of thought to accord to mass priority over movement. We have, therefore, in the electromagnetic theory of the origin of matter the assertion of a reality more fundamental than material reality. Is not this in full accord with the philosophical doctrine that movement is original and that things are derived from movement? "There are changes, but there are not things which change: change does not need a support. There are movements, but there are not necessarily constant objects which are moved; movement does not imply something that is movable."[2] The ground of this principle of original movement is that there is no way of deriving movement from immobility, because movement is more than immobility and the more cannot be derived from the less, but from movement we can derive immobility. Given original things, be they material atoms or the immutable Form or Essence of the Platonic Ideas, movement is something added

[1] Poincaré, *Dernières Pensées*, p. 201.

[2] Bergson, *La perception du changement.*

to them from without, or else it is not part of their reality but only an appearance. On the other hand, given original movement, things are derived by simple interruption, they are arrests or stops of a movement.

If, then, there be original movement where are we to look for it, and how are we to know that it is original? Clearly there is only one reality that can be original movement if we accept the Principle of Relativity. It can only be the reality we know in life and consciousness. Physical science offers us no standard of reference which is absolute, no unit of extension, no unit rate of time flow. The axes by which the universe is coördinated for each observer take the observer as their center and vary as his system of reference varies. This system of reference is to other systems a movement of relative translation. What then is there that is not relative in this universe of relations? Can there be any other answer than that it is the duration of the universe? And then what meaning can we give to this duration but that the universe lives, that is, that it is conscious in the widest sense of the term consciousness? The universe may not be conscious in the narrow sense of awareness or of individual self-consciousness. Whether it is or not is something which by the nature of the case we cannot possibly know. But that it is conscious in the sense that it endures as a living creature endures, by carrying along its past in its present activity; that it must be conceived as a living thing and not as the inert thing we call matter; this seems to be the plain deduction from the nature of knowledge and experience. There must be something absolute, and if the theory of relativity is true this is not space and time, nor any physically real entity fixed in relation to them. If continuity is not to be found in a physical principle it must lie in a spiritual principle. The Principle of Relativity therefore has an important metaphysical implication.

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